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APPLICATION NUMBER: ***60/556,535***
FILING DATE: ***March 26, 2004***
RELATED PCT APPLICATION NUMBER: ***PCT/US05/09808***

Certified by

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14230 U.S. PTO
032604

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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22154 U.S. PTO
60/556535
032604

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Clifford Neal	Prescott	Houston, TX
Jianfeng	Zhang	Houston, TX

Additional inventors are being named on the ____________ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Cryogenic Pipeline Configurations and Methods

Direct all correspondence to: CORRESPONDENCE ADDRESS

[X] Customer Number: 34284

OR

[ ] Firm or Individual Name			
Address			
Address			
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ENCLOSED APPLICATION PARTS *(check all that apply)*

[X] Specification *Number of Pages* 28

[ ] Drawing(s) *Number of Sheets* ____________

[ ] Application Data Sheet. See 37 CFR 1.76

[ ] CD(s), Number ____________

[ ] Other (specify) ____________

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

[ ] Applicant claims small entity status. See 37 CFR 1.27.

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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[Page 1 of 1]

Respectfully submitted,

SIGNATURE [signature]

TYPED or PRINTED NAME Martin Fessenmaier

TELEPHONE 714-641-5100

Date 03/26/04

REGISTRATION NO. 46697
(if appropriate)
Docket Number: 100325.0251PRO

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FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160.00

Complete if Known	
Application Number	
Filing Date	March 26, 2004
First Named Inventor	Clifford Neal Prescott
Examiner Name	
Art Unit	
Attorney Docket No.	100325.0251PRO

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	160.00

SUBTOTAL (1) ($) 160.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($)

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

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1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ________

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SUBMITTED BY				(Complete *(if applicable)*)	
Name *(Print/Type)*	Martin Fessenmaier	Registration No. *(Attorney/Agent)*	46697	Telephone	714-641-5100
Signature	[signature]			Date	March 26, 2004

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CRYOGENIC PIPELINE CONFIGURATIONS AND METHODS

Field of The Invention

Configurations and methods for pipelines in which subcooled materials (typically at least below –200 °F) are transported.

Background of The Invention

Current configurations and methods for cryogenic pipelines typically involve the use of low pressure or vacuum environments in an insulating space around a product pipeline to achieve the desired thermal performance characteristics. While low pressure or vacuum systems often provide relatively good insulation, operation and maintenance of such systems tends to be energy consuming, and frequently becomes problematic where such pipelines are submerged on, or even below the sea bed.

Among other uses, cryogenic pipelines (and especially LNG pipelines) are increasingly used in configurations for offshore LNG loading and unloading terminals. However, various difficulties are often encountered, and most typically associated with thermal expansion, compression, and/or structural stability. For example, Villatte describes a cryogenic pipeline in U.S. Pat. No. 6,145,547 in which the product pipeline is typically manufactured from INVAR™ (36% Nickel steel), which has very low expansion and contraction properties. While thermal stress in such pipelines is almost completely avoided, various disadvantages nevertheless remain. For example, INVAR™ steal is relatively expensive, and therefore often cost-prohibitive. Moreover, generation and maintenance of the low pressure (*e.g.*, 100 mbar) in the pipeline assembly requires considerable energy.

In other known configurations, as described in U.S. Pat. No. 6,568,431 to Marchal, buckle strength is improved by adding fluting to the pipelines. However, addition of flutings along the length of the pipeline typically increases production cost, and typically complicates manufacture, handling, and/or maintenance.

Therefore, while various methods and configurations for cryogenic pipelines are known in the art, all or almost all of them suffer from several disadvantages. Therefore, there is still a need for improved configurations and methods for cryogenic pipelines.

Detailed Description

The inventors discovered that pipelines transporting material at sub-ambient temperature, and especially cryogenic material can be constructed in a manner such that the pipeline has both increased mechanical stability and desirable thermal insulation properties while maintaining a mechanically simple structure, which is relatively inexpensive to manufacture and install.

In one especially preferred aspect of the inventive subject matter, a plurality of bulkheads (non-metallic, hybrid, or metallic) and spacers are employed to create an annular space between a product pipline and a outer pipeline, wherein the annular space is at least partally filled with a microporous or nanoporous insulating material. The bulkheads are preferably configured (and coupled to the inner and outer pipeline) such that the bulkheads transfer the contraction induced axial compression load on the inner cryogenic product pipeine(s) to the outer jacket pipeline. In most embodiments of such pipelines, the pressure in the annular space will be ambient pressure. Consequently, it should be appreciated that the so configured pipe(s)-in-pipe system functions as a structual column, with thermal insulation maintained in the annular space in an ambient pressure environment, thereby eliminating the need for expensive alloys, vacuum generation/maintenance, or use of expansion bellows.

More particularly, in preferred aspects of the inventive subject matter, the bulkheads that connect the inner and outer pipelines at the ends of the pipeline balance compression forces with rigidity of the outer pipeline. In such configurations, contraction forces transferred to the external pipeline, which is thereby compressed. To prevent buckling, spacers (*e.g.*, thermally isolating) are placed around the inner product pipeline that maintain a predetermined distance between the pipes, while further cryogenic foam (*e.g.*, nanoporous or microporous foam) is placed around the remaining surface of the product pipeline. It should be especially appreciated that such pipeline configurations advantageously allow use of 9% nickel steel for the product pipeline to reduce cost of manufacture.

Further mechanical stability may be imparted by placing the pipe-in-pipe assembly in a restraining environment. For example, contemplated pipelines may be placed in a trench with select back-fill material installed over the pipeline. Therefore, in such configurations, the load on the bulkheads and outer pipeline is transferred into the surrounding soil. Similarly, the pipelines can also be constrained above ground. For example, the pipeline may be placed on a foundation of sleepers that contain sliding or gimbaled supports.

While not limiting to the inventive subject matter, it is generally preferred that two bulkheads cooperate to seal the annular space between the bulkheads. In such configurations, it is typically preferred that the annular space is kept at ambient pressure. Particuilarly preferred materials for an LNG product pipeline comprises 9% nickel steel, while the outer pipeline comprises carbon steel. The preferred thermal insulation comprises a high performance nano-porous aerogel product in blanket or bead form installed within the annular space. Such aerogels may be applied in any form, however, preferred forms include flexible sheets, or spray-coated materials. It should be further recognized that installation of pre-fabricated and assembled pipelines can be done by numerous known manners, and especially include towed method of installation. Alternatively, the pipeline may also be installed by a surface barge. Thus, it should be appreciated that the invention improves the existing art in three areas: Reduction of pipeline cost, increased pipeline reliability, and reduction in maintenance requirements.

While contemplated cryogenic pipeline configuration and methods are preferably employed for LNG offloading and offshore LNG terminals, numerous alternative uses are also considered suitable herein. For example, contemplated alternative uses include transfer lines for floating LNG production, storage, and offloading vessels, liquid hydrogen and oxgen fueling lines for aerospace or other applications, and all applications that need to transport cryogenic products through pipelines. Still further contemplated uses include LPG transport, or transport of gases and liquids having a temperature below ambient temperature (*e.g.*, liquefied carbon dioxide, LPG, liquid nitrogen, etc.). Exemplary configurations and additional modifications are provided in the following presentation materials, which form part of the diclosure.

Insulated LNG Pipeline Configuration

- **Configuration Concept**
  - **Pipe-in-Pipe (or multiple pipes-in-pipe)**
    - Internal Pipe is used as a product transfer pipeline, which is a metallic pipe rated for LNG service
      - ↗ Examples of Internal Pipe for LNG Service
        - ASTM 333 Grade 8, 9% Nickel Steel
        - ASTM A312 Grade TP, 316L Stainless Steel
    - External Pipe is used as a casing pipe, which is a metallic pipe rated for pipeline service
      - ↗ also used as a structural member to contain the internal pipe in a dry environment
      - ↗ And to be used to contain the expansion and contraction forces from the inner pipe by the use of bulkheads attaching the inner and outer pipelines
      - ↗ and to contain an insulating material in the annular space between the inner and outer pipe, which is maintained in an ambient pressure environment resulting from the sealed bulkheads.
        - Examples of External Pipe for Casing Service are ASTM X-52 with external fusion bonded epoxy (FBE) corrosion coating and external concrete weight coating if required.

Insulated LNG Pipeline Configuration

◈ Configuration Concept

– Insulation

- Insulation is installed in the annular space and between bulkheads.
  - ↗ Nano-porous insulation may be in the form of flexible blankets like that manufactured by Aspen Aerogels, Inc. as their "Flexible Aerogel Blanket". The insulation is wrapped around the inner pipe to form a complete seal of insulation in the annular space.
  - ↗ Nano-porous insulation may be in the form of beads like that manufactured by Cabot Corporation, Inc. as their Nanogel™ insulation material. The insulation is installed in the annular space completely filling the void.
- Insulation is used to insulate the cryogenic product within the inner pipe to maintain its low cryogenic temperature.

Insulated LNG Pipeline Configuration

- **Configuration Concept**
  - **Bulkheads**
    - Used to isolate the annular space between the inner product pipe and the external casing pipe to provide an ambient pressure environment for thermal insulation
    - Used to transfer the thermal expansion and contraction loads from the inner pipe to the outer pipe, such that the combined configuration acts as a structural member with the pipes being constrained by
      - internal centralizer spacers, which position the inner product pipe within the outer casing pipe as an aide during installation and as an aide in transferring internal loads to the external pipe.
      - and external soil filled trench, which aides in aligning the pipe-in-pipe configuration for load transfer to the surrounding soil
      - Or by external pipeline supports which support the pipe when used above ground, and which align the pipeline to aide in transferring the pipeline loads to the soil.
    - May be metallic or non-metallic composition, or a combination of both and designed to minimize thermal heat loss / intrusion by their configuration and design, and sufficiently strong to resist the load transfer between the inner and outer pipe.

Insulated LNG Pipeline Configuration

Configuration Concept

- Spacer / Centralizers
  - Used to centralize and space the inner product pipe within the external casing pipe
  - Used to assist in the transfer of the thermal expansion and contraction loads from the inner pipe to the outer pipe, such that the combined configuration acts as a structural member.
  - May be metallic or non-metallic composition, or a combination of both and designed to minimize thermal heat loss / intrusion by their configuration and design, and sufficiently strong to resist the load transfer between the inner and outer pipe.
  - Used also as an installation aide during fabrication to allow installation of the outer pipe over the inner insulated pipe.
  - Used during operation of the cryogenic pipeline to ensure insulation is not crushed or damaged in service.

Insulated LNG Pipeline Configuration

- **Configuration Concept**
  - Pipe-in-pipe configuration is sealed to provide an ambient atmosphere for the protection of the cryogenic insulation.
  - Subsea Application
    - Pipeline may be installed in a trench to assist in transmitting frictional forces to the soil and for protection
    - Pipeline may be installed on the seabed and covered with natural material, matting or other man-made materials to assist in transferring frictional forces to the soil and for protection.
  - Onshore Application
    - Pipeline may be installed in a trench or on a prepared bed with covering to assist in transmitting frictional forces to the soil and for protection.
    - Pipeline may be installed above ground on prepared pipe supports with restraints to assist in transmitting forces to the soil.

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Insulated LNG Pipeline Configuration

◆ Configuration Concept

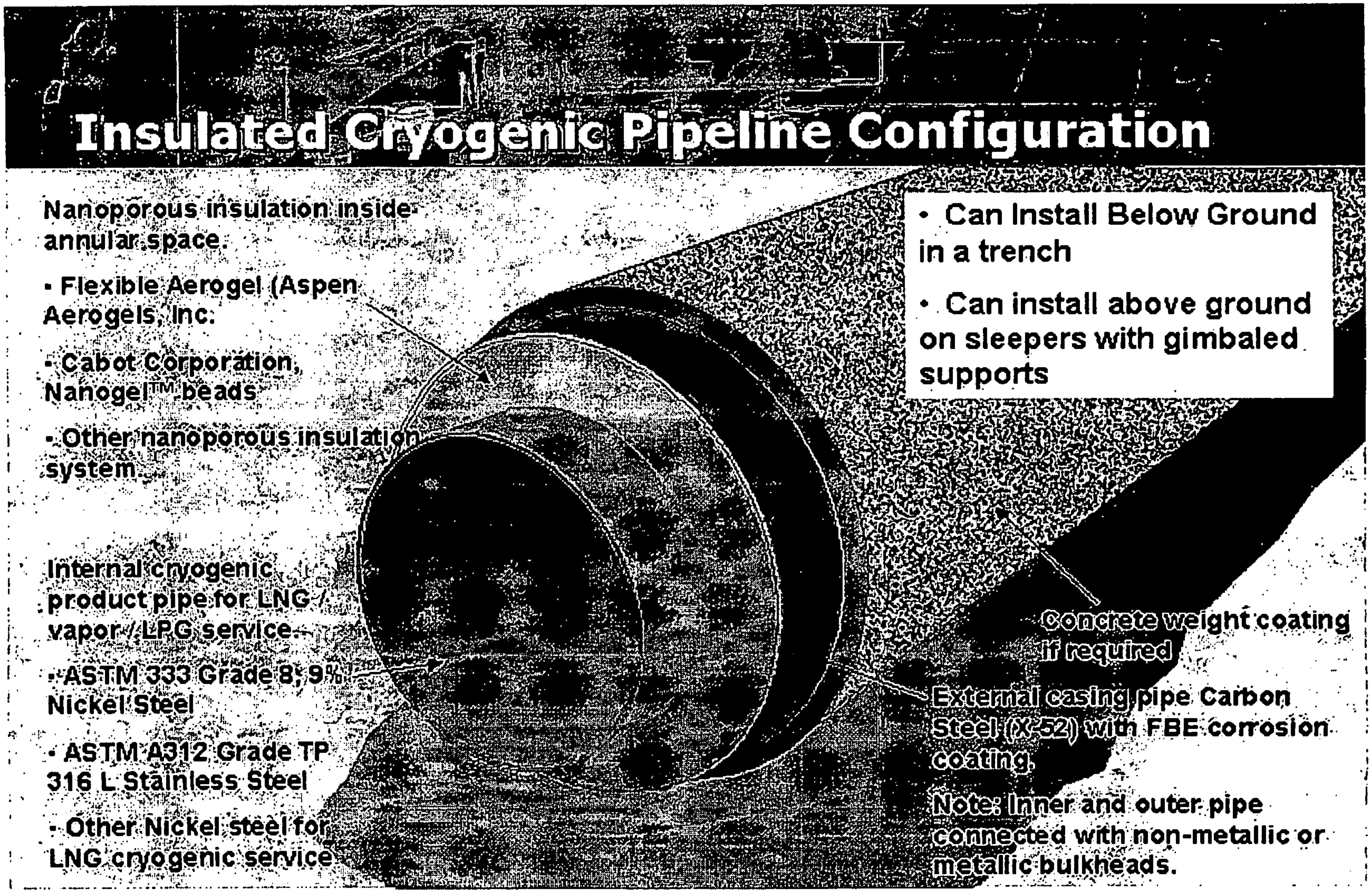
– Pipe-in-pipe configuration may be instrumented with sensors (fiber-optic or electrical) to measure

- Pressure in internal product pipe
- Pressure in the insulated annular space
- Temperature in internal product pipe
- Temperature in the insulated annular space
- Heat Flux in the insulated annular space
- Displacement of internal pipe with respect to outer pipe
- Slug detection of product in inner pipe

Insulated LNG Pipeline Configuration

◈ Configuration Concept

- Pipe-in-pipe configuration may be used in a multitude of applications
  - Transfer of cryogenic product (LNG, LPG, etc)
    - ↗ From offshore receiving terminal to host processing and storage platform
    - ↗ From onshore liquefaction terminal to offshore / onshore off-loading terminal
    - ↗ From marine receiving terminal to onshore plant


Insulated Cryogenic Pipeline Configuration
Nanoporous insulation inside annular space.
• Flexible Aerogel (Aspen Aerogels, Inc.
• Cabot Corporation, Nanogel™ beads
• Other nanoporous insulation system
Internal cryogenic product pipe for LNG / vapor / LPG service
• ASTM 333 Grade 8, 9% Nickel Steel
• ASTM A312 Grade TP 316 L Stainless Steel
• Other Nickel steel for LNG cryogenic service
• Can Install Below Ground in a trench
• Can install above ground on sleepers with gimbaled supports
Concrete weight coating if required
External casing pipe Carbon Steel (X-52) with FBE corrosion coating.
Note: Inner and outer pipe connected with non-metallic or metallic bulkheads.

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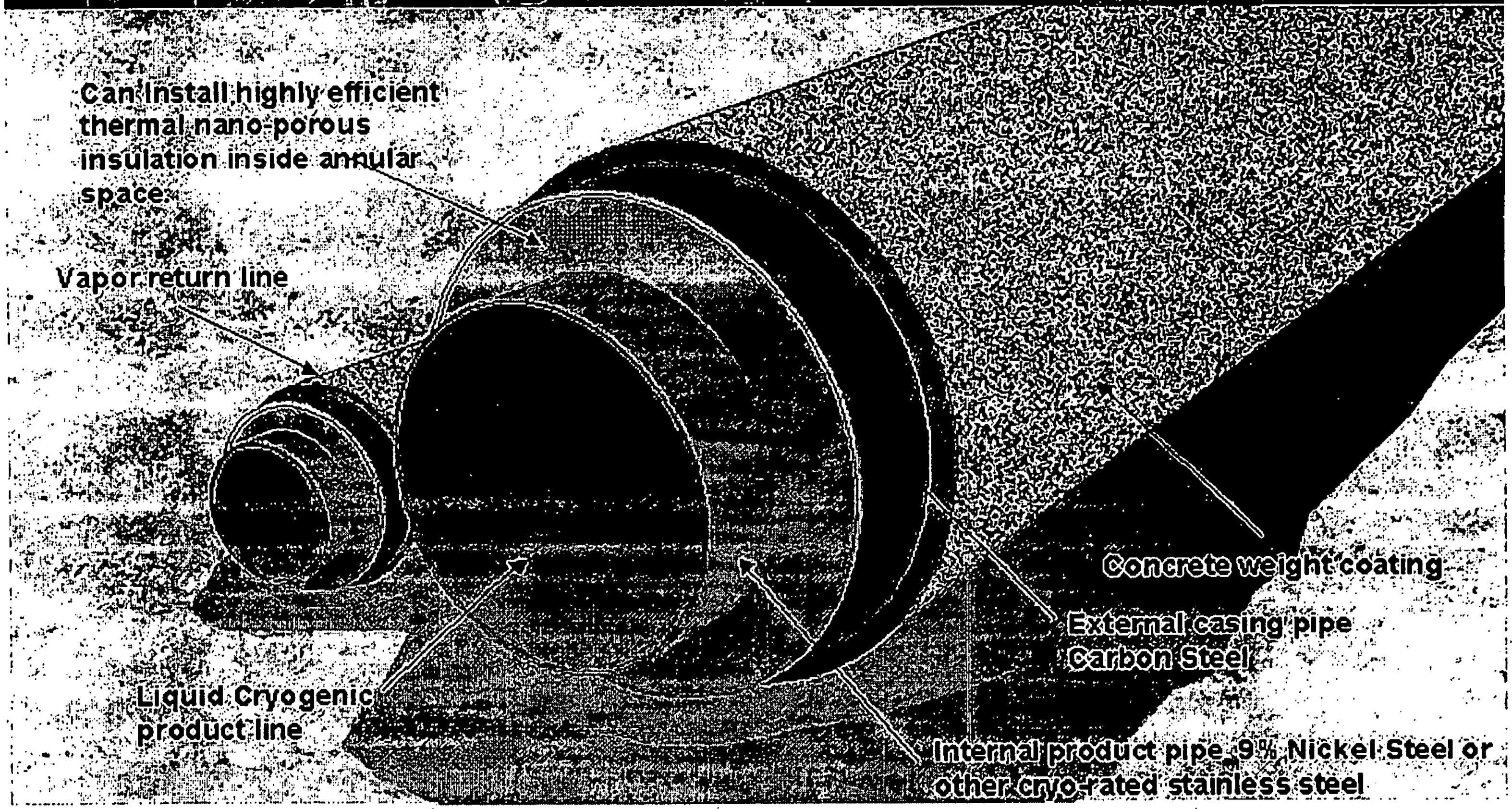
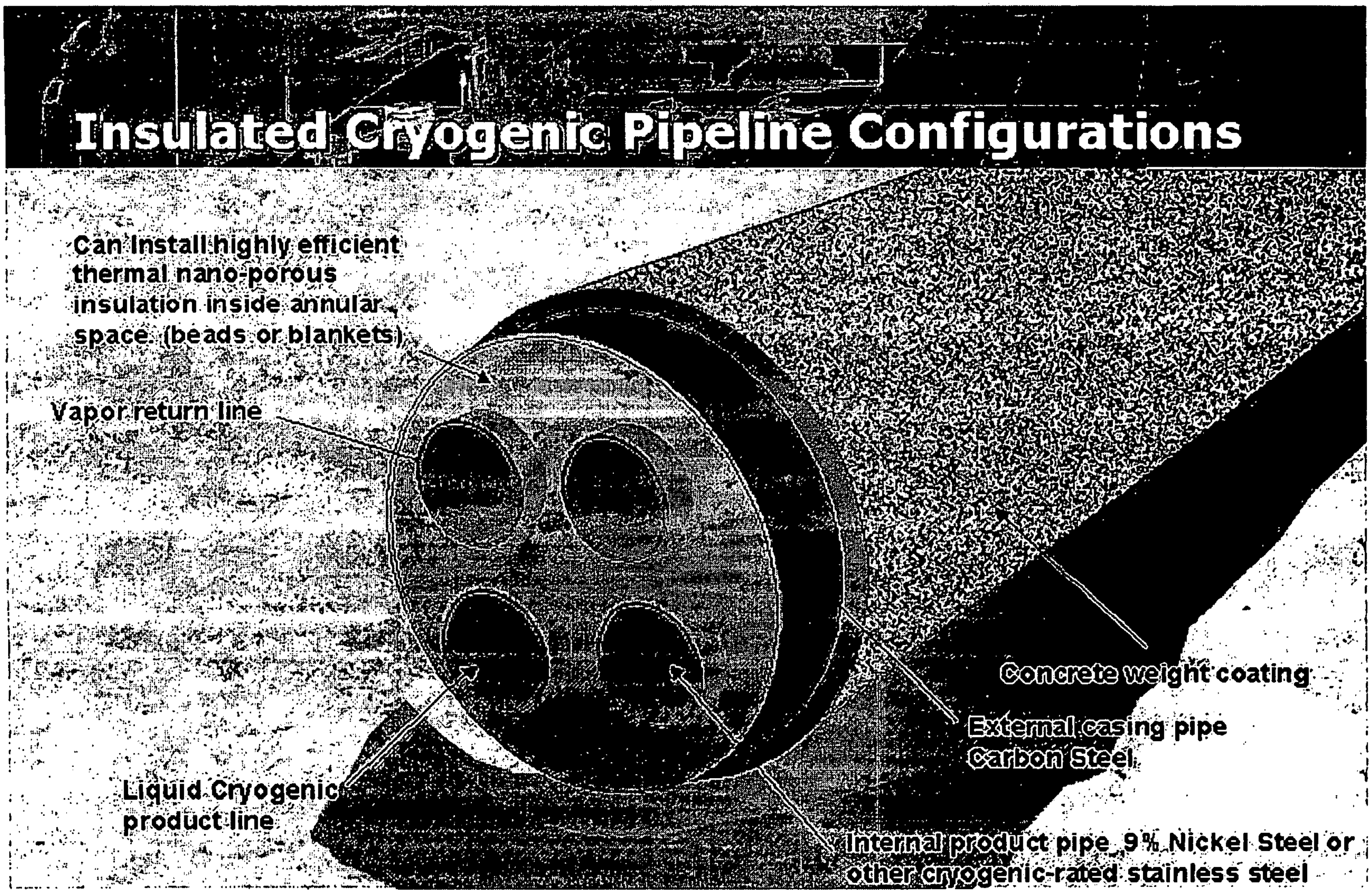
Insulated Cryogenic Pipeline Configurations

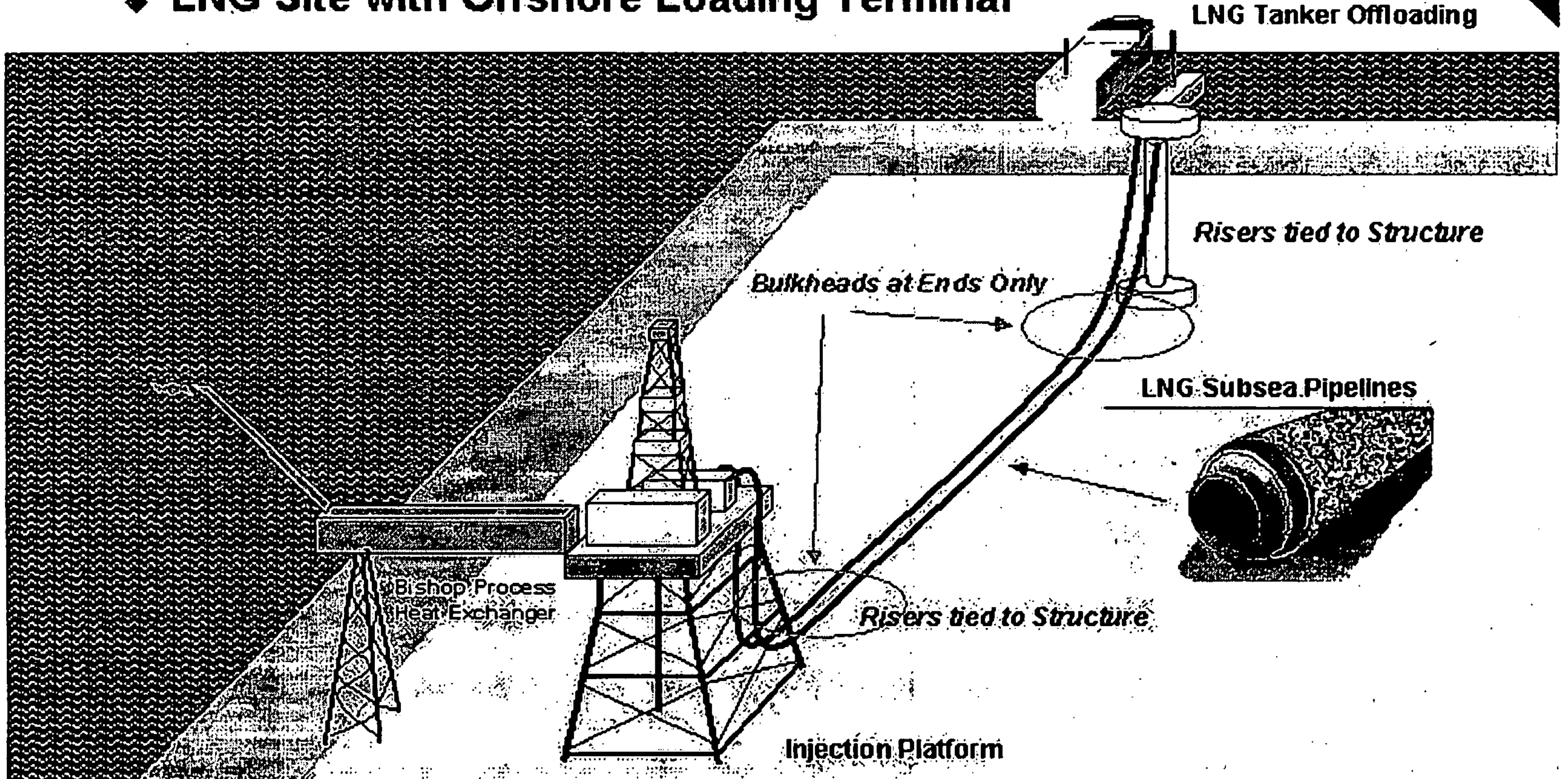


FLUOR 9 CONFIDENTIAL LNG Subsea Pipeline Insulation.ppt


Insulated Cryogenic Pipeline Configurations
Can install highly efficient thermal nano-porous insulation inside annular space. (beads or blankets)
Vapor return line
Liquid Cryogenic product line
Concrete weight coating
External casing pipe Carbon Steel
Internal product pipe 9% Nickel Steel or other cryogenic-rated stainless steel

Cryogenic Subsea Pipeline - Bundle Concept

- LNG Site with Offshore Loading Terminal



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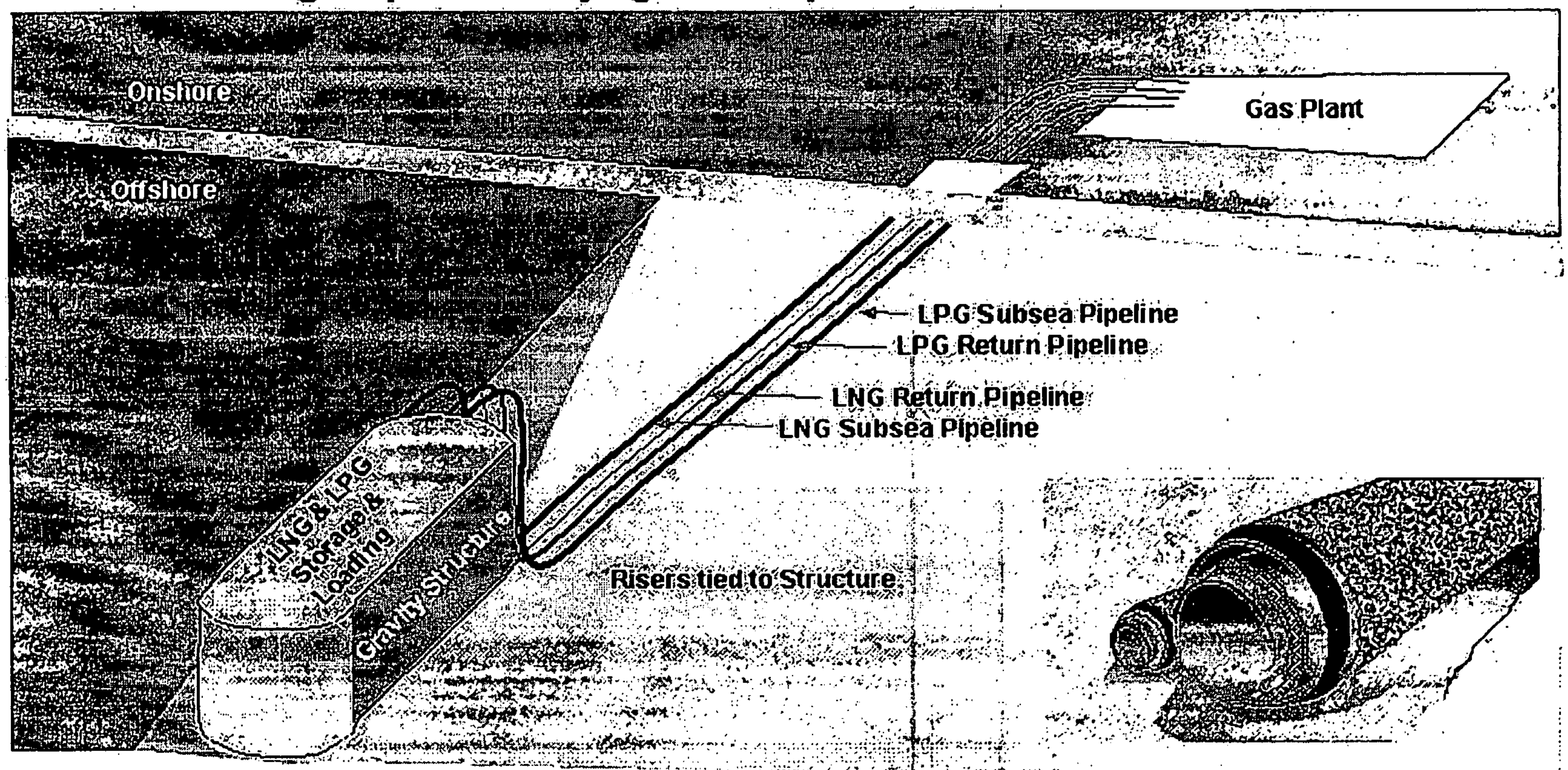
Cryogenic Subsea Pipelines - Conceptual Layout

- Using Separate Cryogenic Vapor Return Lines



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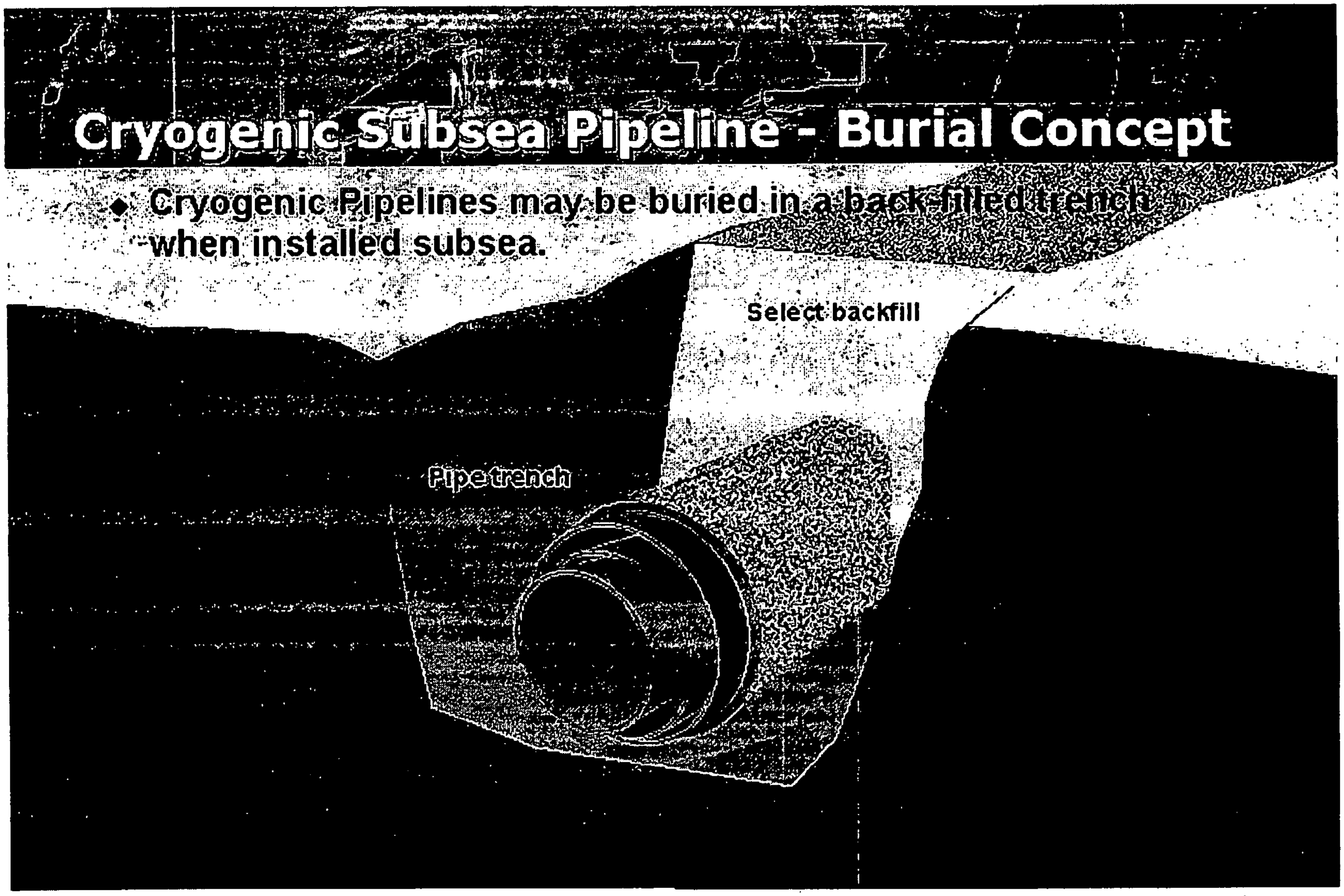

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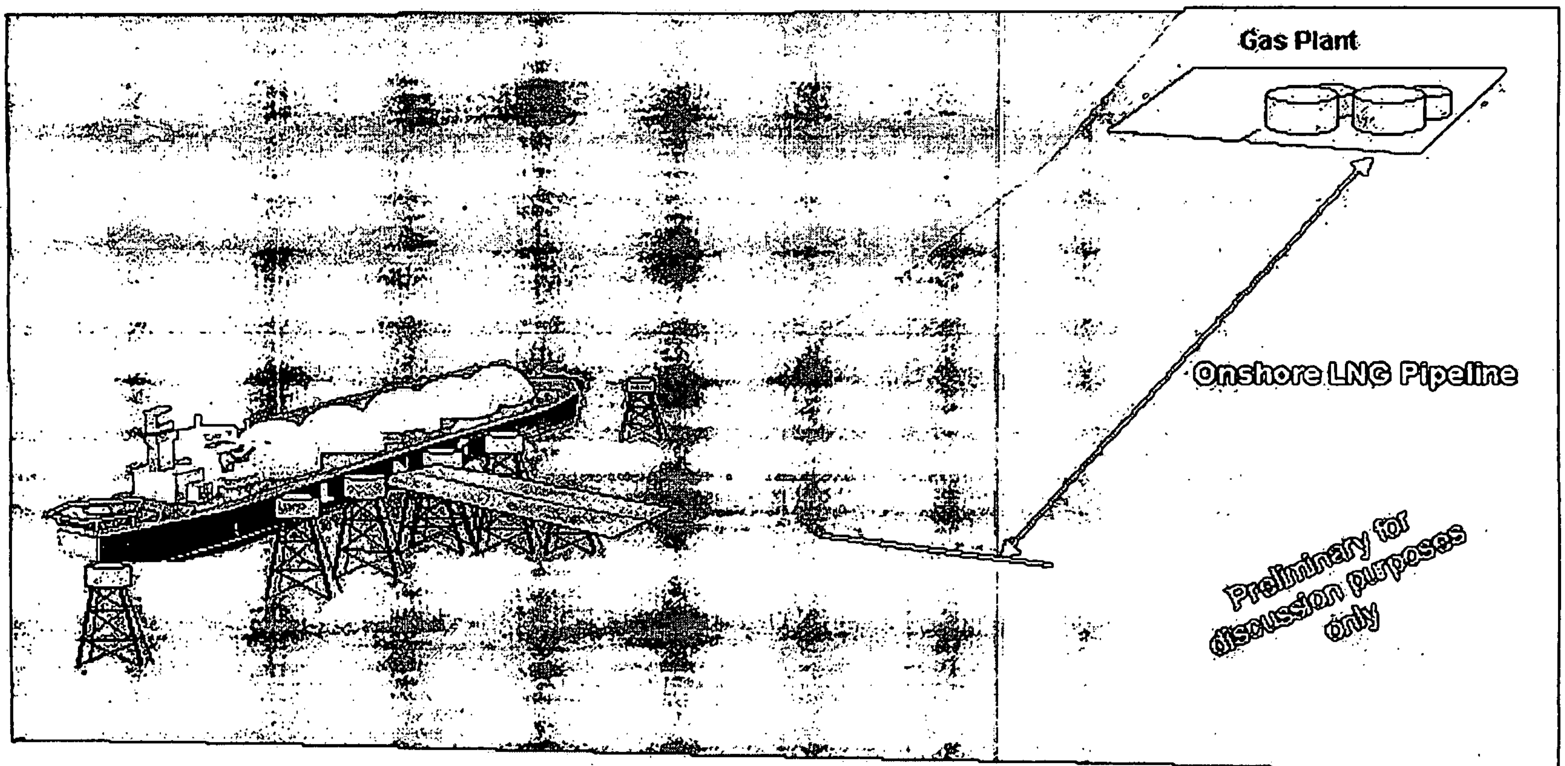
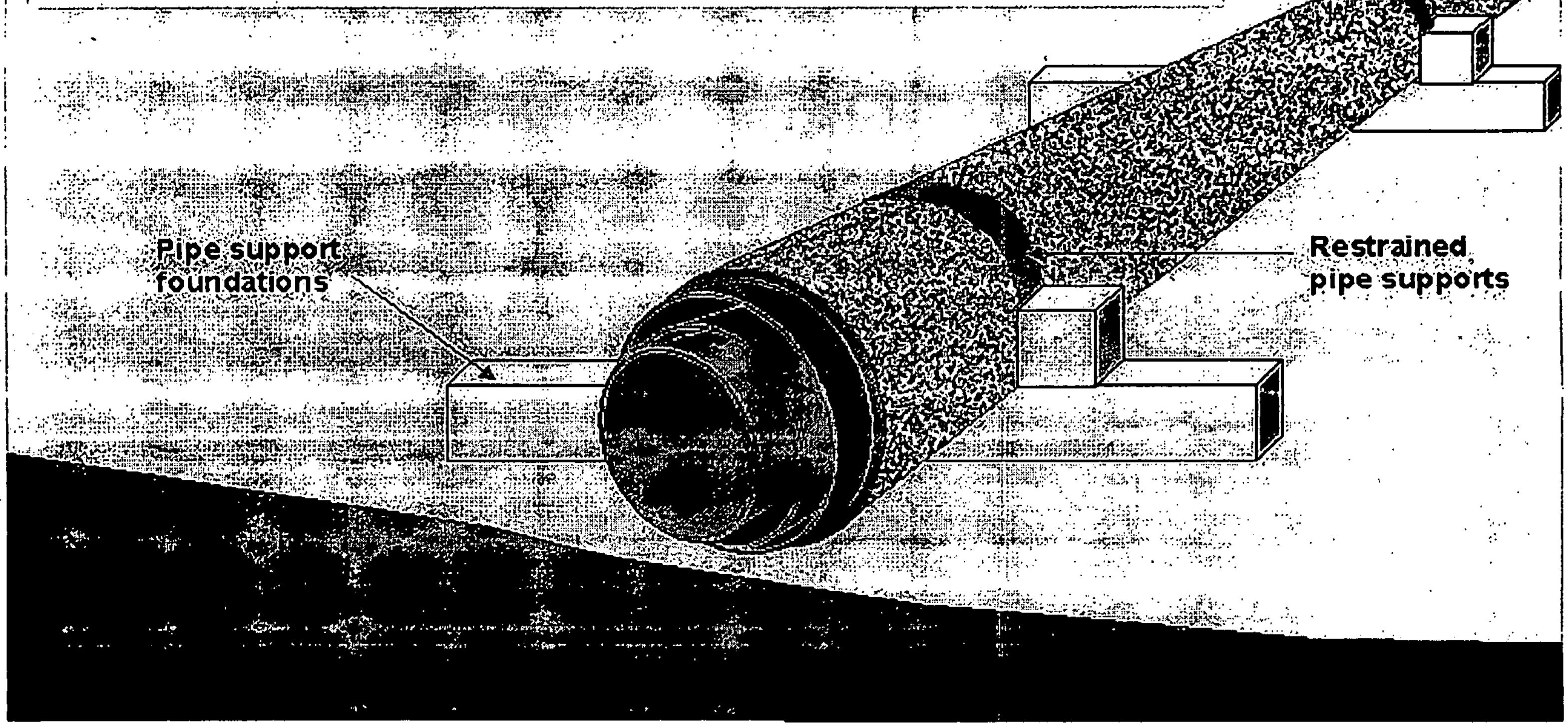
Cryogenic Pipeline - Conceptual Layout

- Cryogenic Site with Tanker Terminal for loading / offloading



Cryogenic Pipeline – Above Ground Concept

- LNG Pipelines may be installed on pipe supports with restraints when installed above ground.



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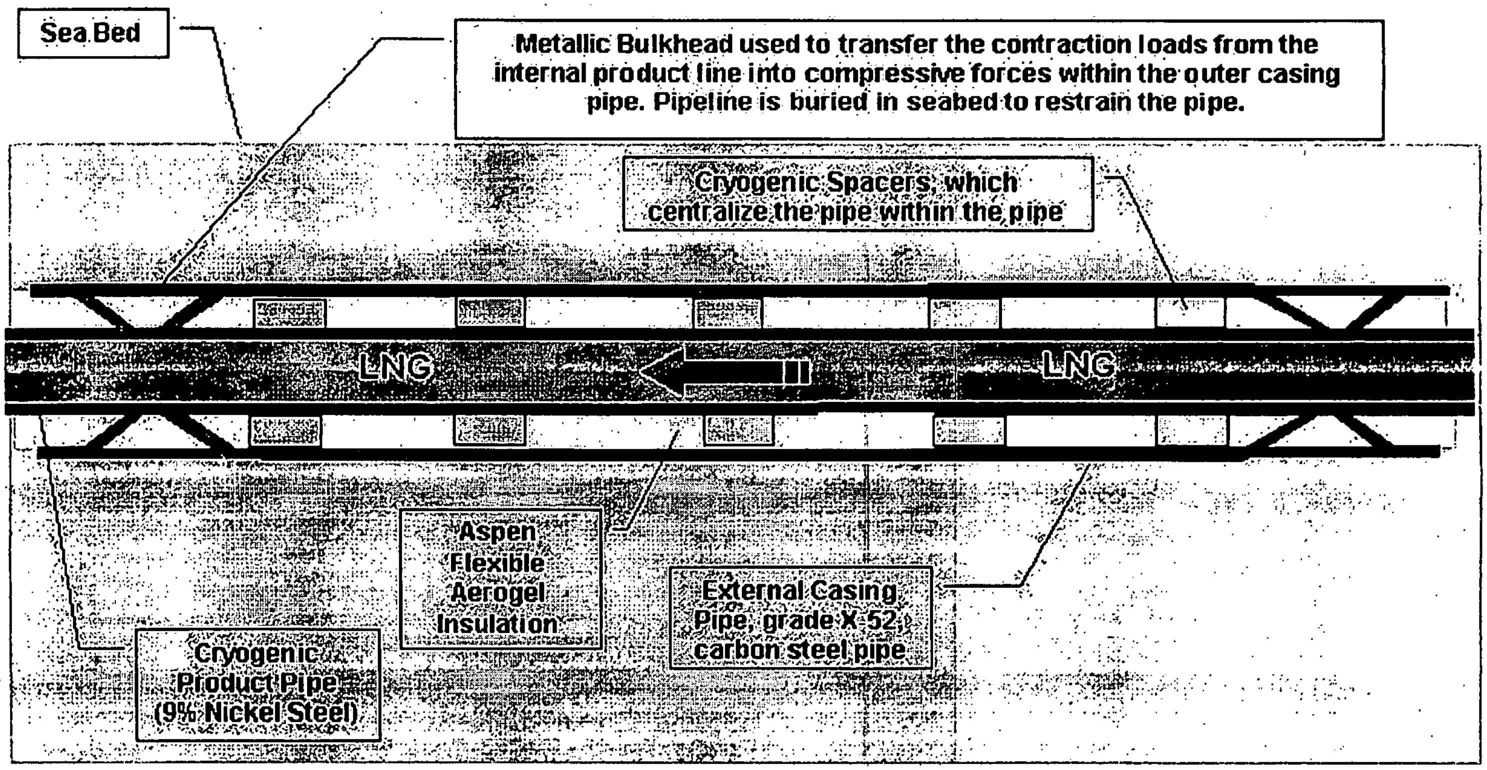
Subsea cryogenic pipe – Metallic bulkhead concept



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Preliminary for Discussion Purposes Only

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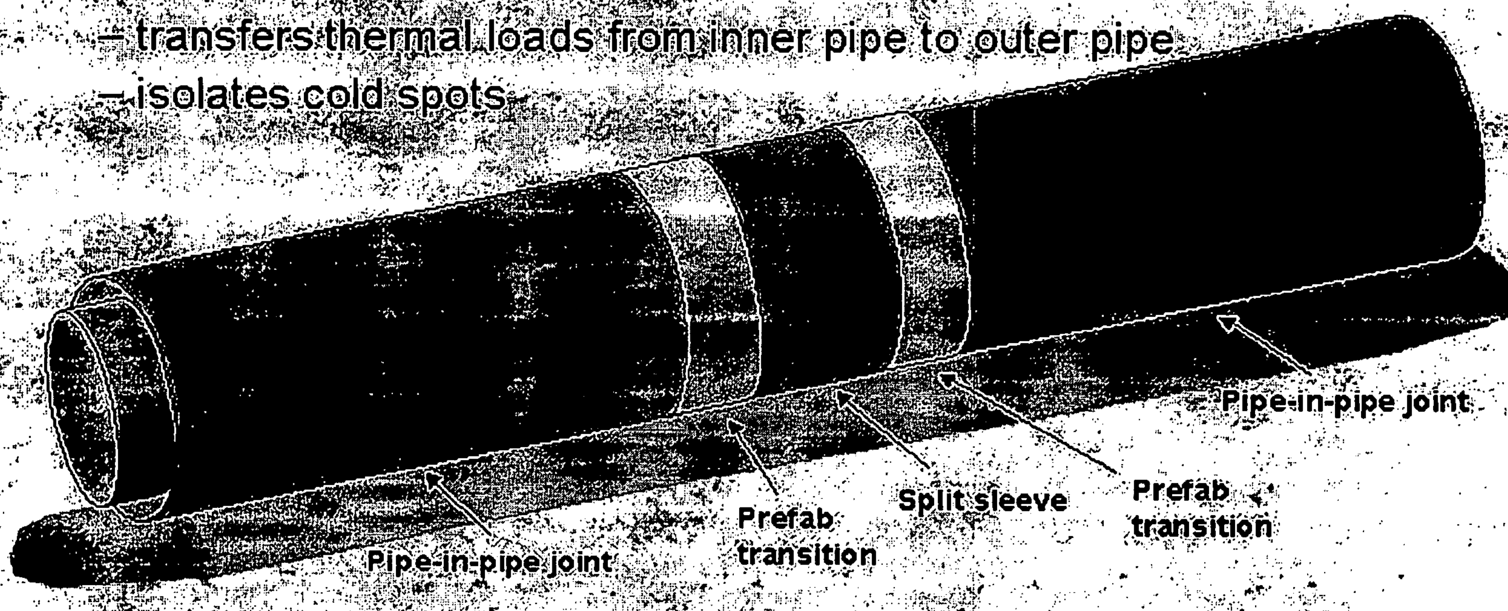
Cryogenic Subsea Pipeline – Metallic Bulkheads

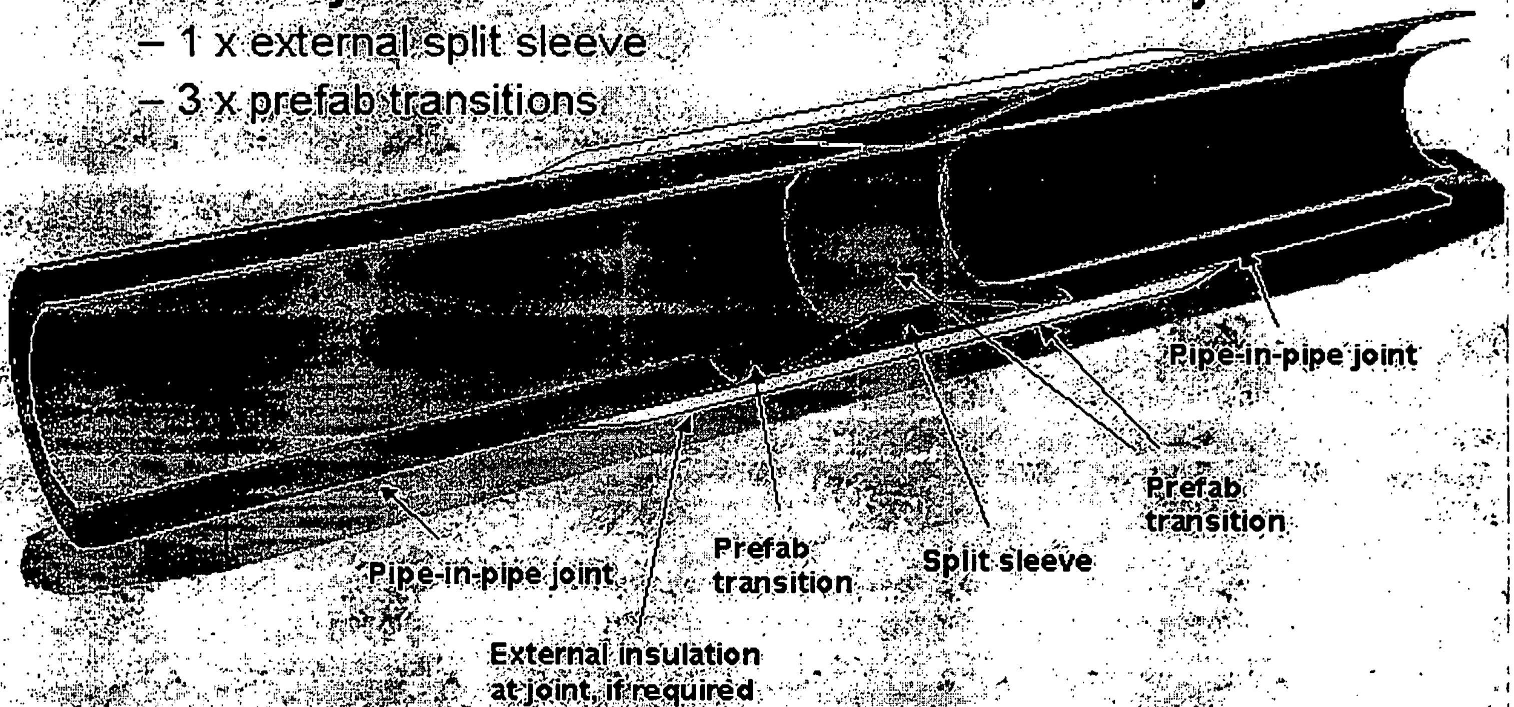
- Bulkheads
  - at ends only OR at regular intervals
  - for pipe-in-pipe solutions
  - transfers thermal loads from inner pipe to outer pipe
  - isolates cold spots

Note: External insulation at bulkhead not shown in this view.

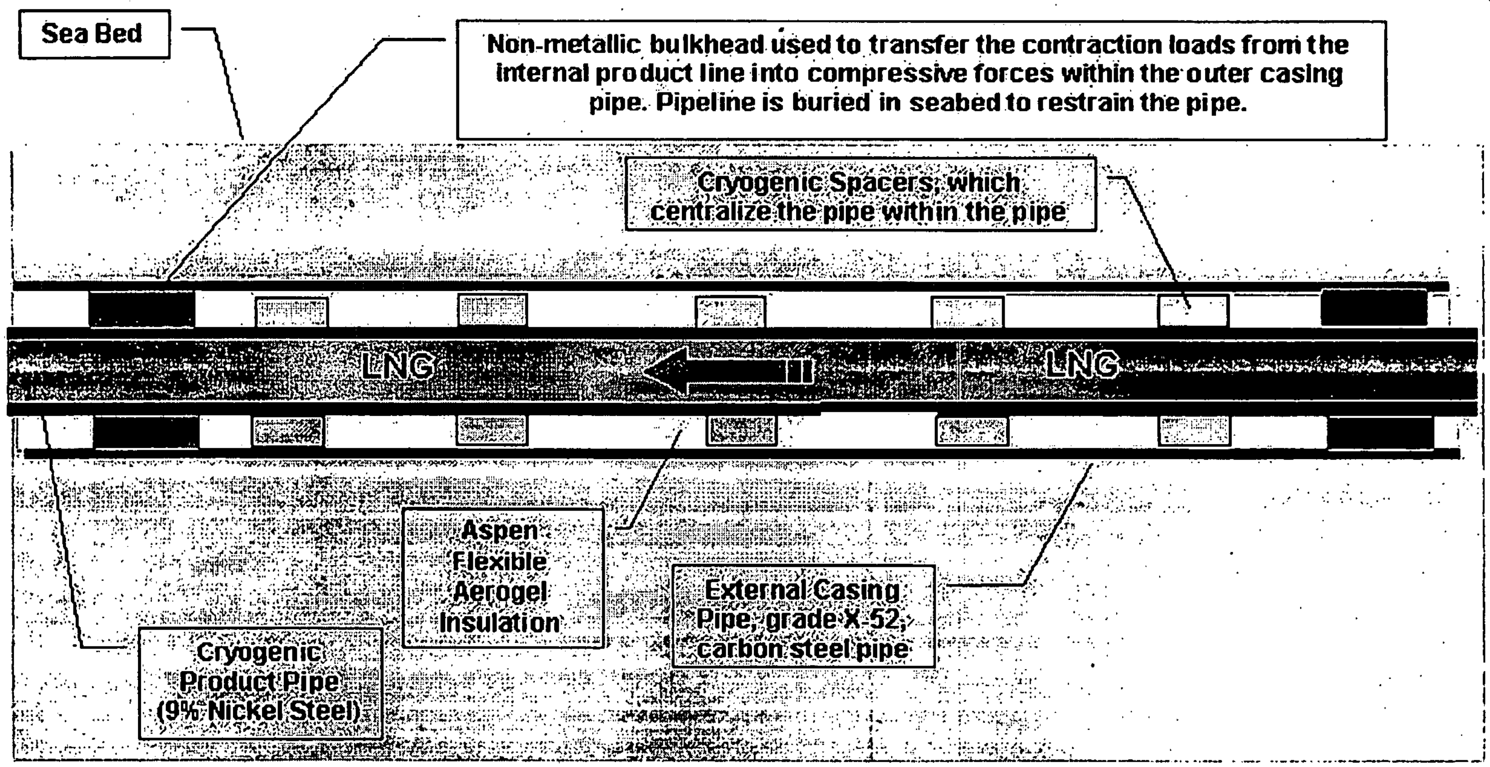


Cryogenic Subsea Pipeline – Metallic Bulkhead Details

- Cut-Away view of metallic bulkhead at field joint
  - 1 x external split sleeve
  - 3 x prefab transitions



Subsea cryogenic pipe – Non-metallic bulkhead concept



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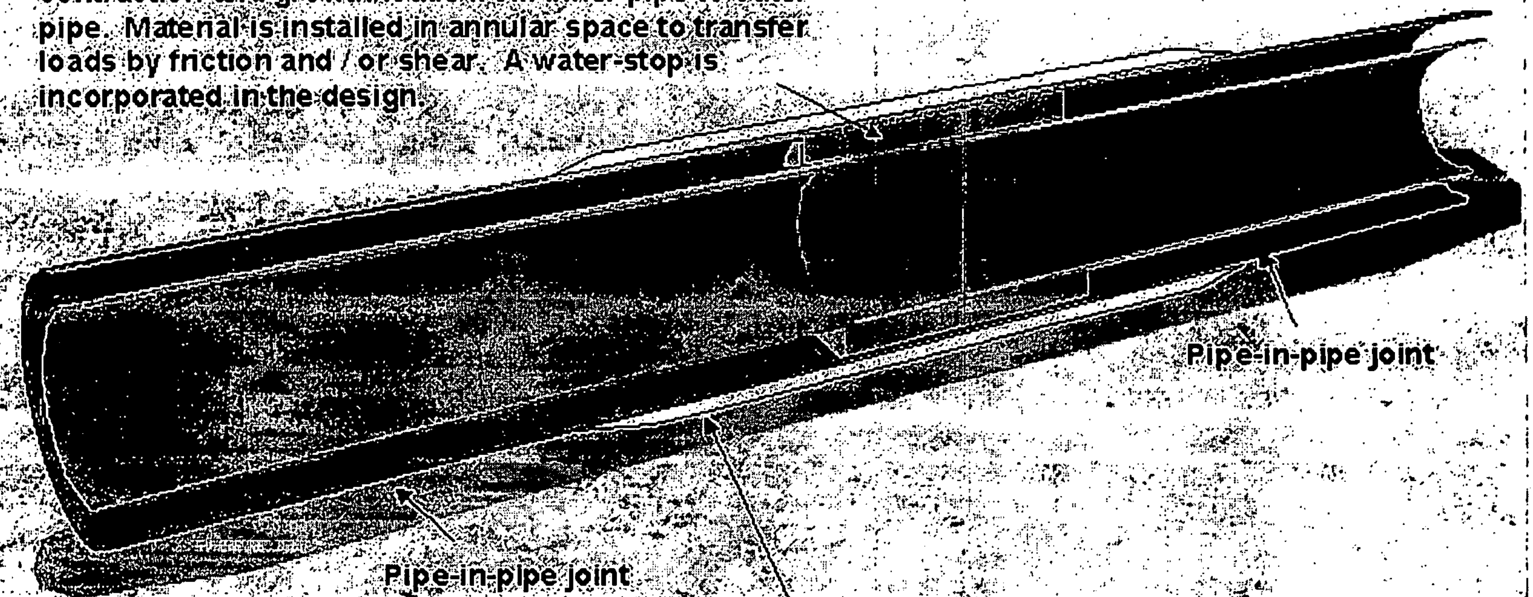
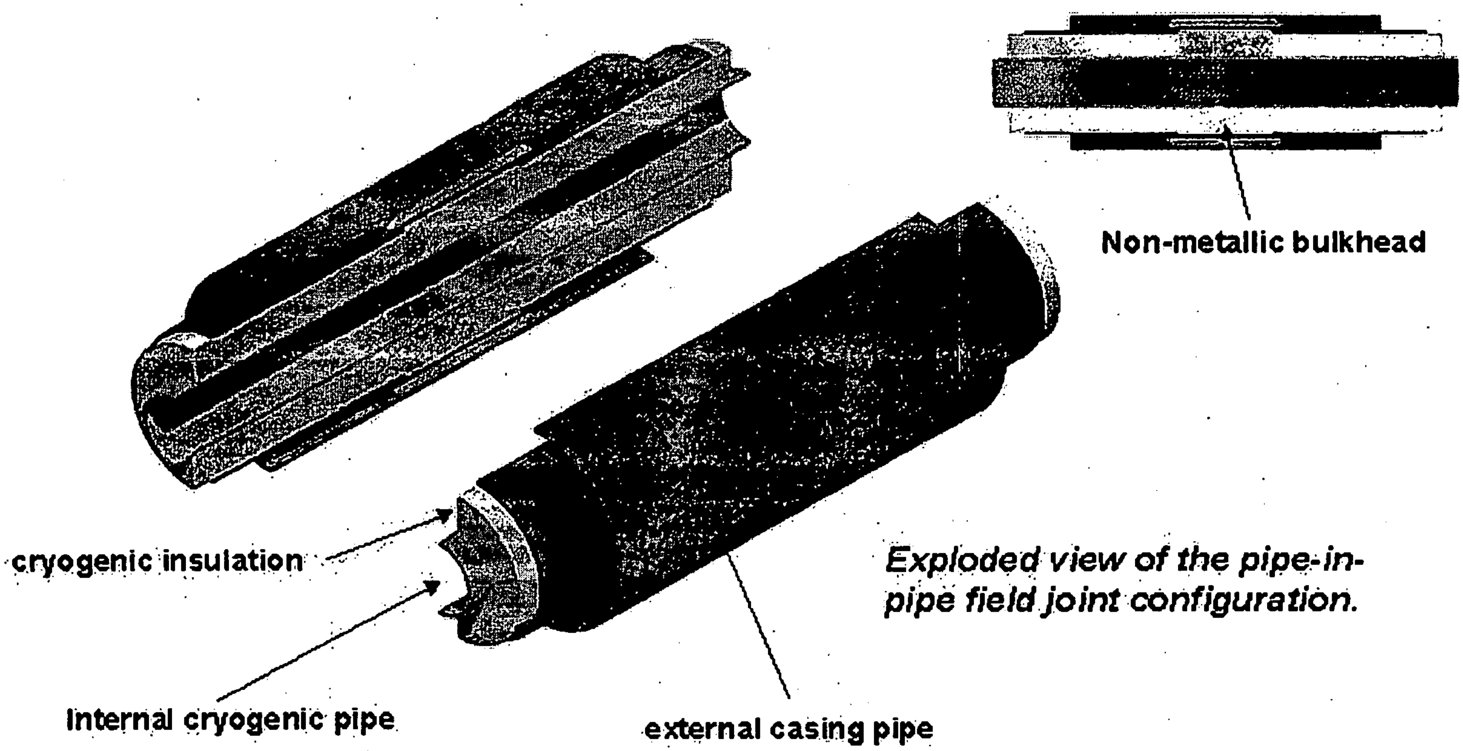
Cryogenic Subsea Pipeline — Non-metallic Bulkhead Details

Non-metallic bulkhead used to transfer thermal contraction and growth loads from inner pipe to outer pipe. Material is installed in annular space to transfer loads by friction and / or shear. A water-stop is incorporated in the design.



Cryogenic Subsea Pipeline — Non-metallic Bulkhead Details



Exploded view of the pipe-in-pipe field joint configuration.

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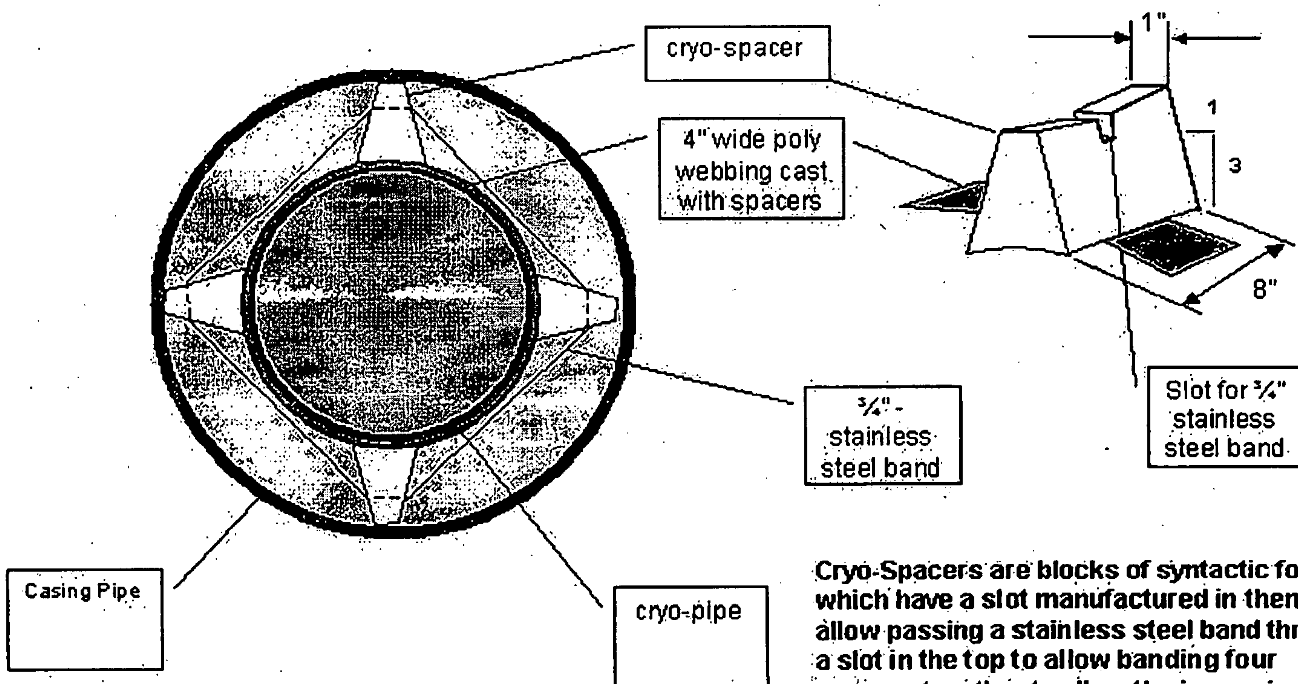
Subsea cryogenic pipe – Example cryogenic spacers / pipe centralizer

nanoporous insulation material that is placed around the inner pipe filling the annulus. The insulation would be placed around and between the spacers / centralizers as well, filling all voids.



Cryo-Spacers are blocks of syntactic foam which have a slot manufactured in them to allow passing a stainless steel band through a slot in the top to allow banding four spacers together to allow the inner pipe to be centralized to the outer pipe.

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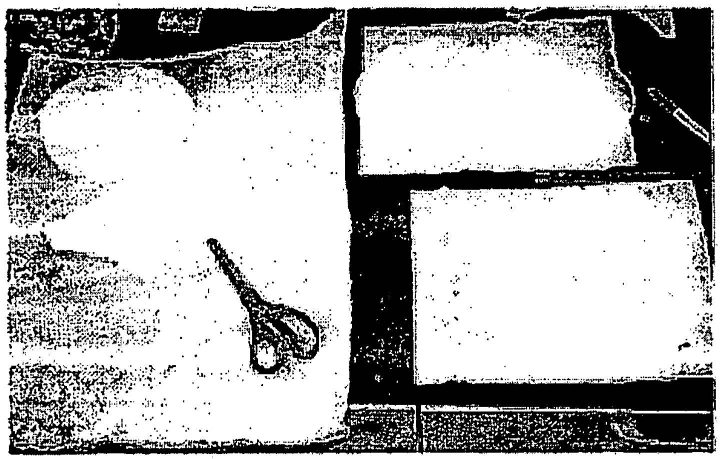
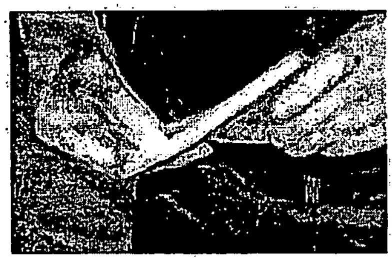
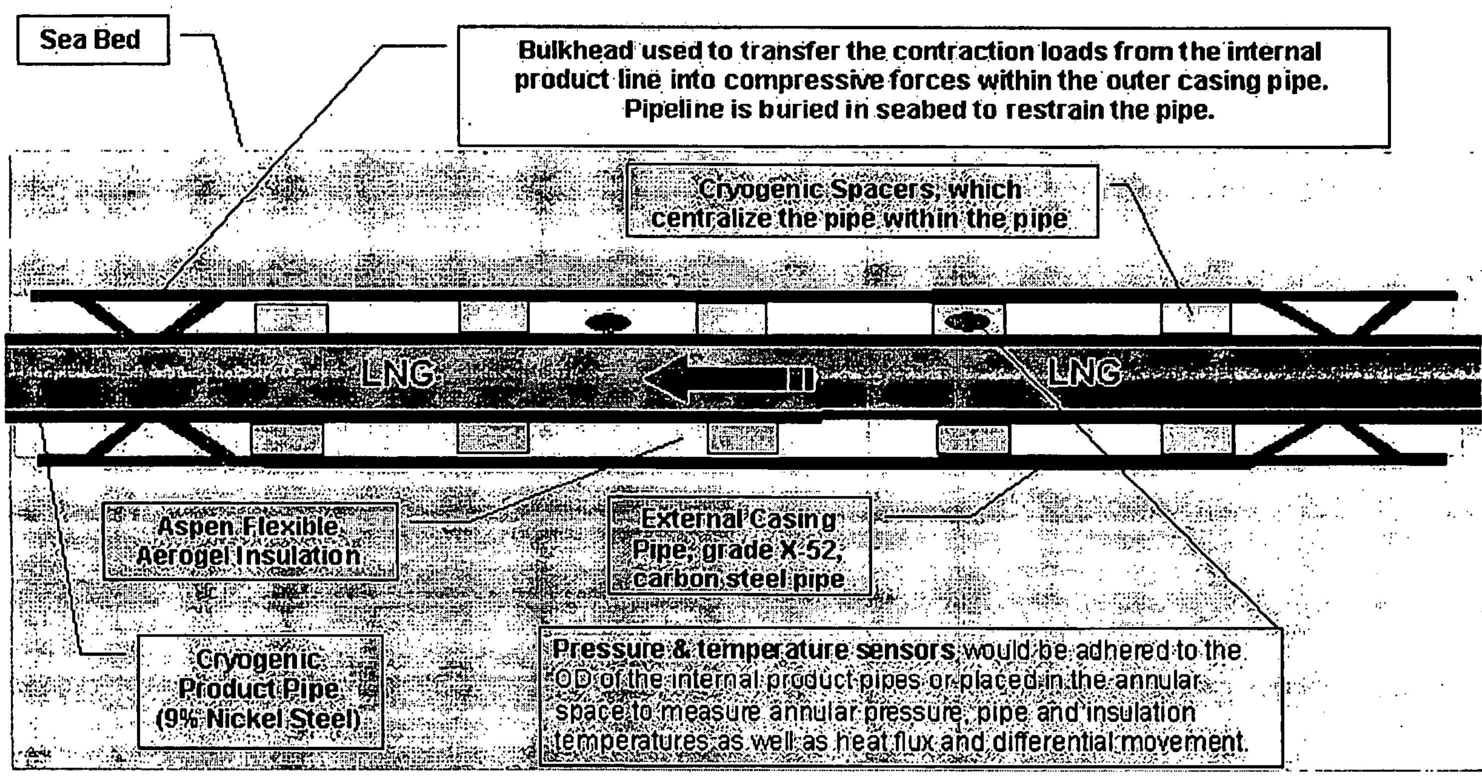
Example of a Flexible Aerogel Blanket





Flexible fiber-reinforced aerogel blanket used as insulation: the pictures show drape, twist flexure and ease of shaping using simple tools like scissors without significant edge damage.

Subsea cryogenic pipe – Monitoring Concept



FLUOR. Preliminary for Discussion Purposes Only

Not To Scale 24 CONFIDENTIAL LNG Subsea Pipeline Insulation.ppt

Thus, specific embodiments and applications of cryogenic pipeline configurations and methods have been disclosed. It should be apparent, however, to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive concepts herein. The inventive subject matter, therefore, is not to be restricted except in the spirit of the present disclosure. Moreover, in interpreting the specification, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.